UPDATE on the AXAF GUIDE and ASPECT STAR CATALOG

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29 May, 1996

OVERVIEW

1. Review of objectives & requirements of the AGASC.
   Justification of expanded format for AGASC1.1
   What was missing in the AGASC1.0?

2. Merging of the PPM into the AGASC1.0
    - PPM - the best complement now available
    - PPM matching
        - choosing the best data
        - final results
            - instrumental mags (m{ACA})
            - surface density

3. The AGASC1.1 - New Data
    - includes proper motion, epoch, variability flag,
        - catalog IDs
        - takes a load off the SSA

4. The AGASC1.1 - New Format
    - Errors
    - Codes & Flags

OVERVIEW - continued

5. What's still needed
    better positions, since pos. errors drive CTI calib.
    colors for more stars to achieve FOM
    more accurate mags/colors for better m{ACA}

    catalog merging
        GSC1.2
        TOC
        GSC2.0 ?

6. Future plans for the AGASC
    updated instrumental ACA mags from on-orbit calibration
        inital OV phase calibration
        re-calibration as ACA specs change
        catalog updating using observed m{ACA}
    AXAF Optical Sky Survey (AOSS):
incorporation of uncatalogued stars
        spoiled or spoiler stars
        useable ACQ/ASPECT stars

OBJECTIVES & REQUIREMENTS

- The primary objective of the ACA is to measure the image positions of selected target stars and fiducial lights in its FOV.

- AXAF-I OBC uses gyro attitude data and ACA image centroids for real-time pointing.

- Post-facto aspect determination is required for observations $>$ 100sec to compensate for the apparent motion of the X-ray image on the SI focal plane.

- When a maneuver is completed, $\geq$2 acquisition stars must be acquired before acquiring guide stars and fiducial lights. Up to 8 images can be tracked. The ground provides expected positions in the ACA FOV for these objects.

- At least 5 stars brighter than $m_{ACA} = 10.2$ should be provided from ground 95% of the time, anywhere on the sky, even at EOL.

JUSTIFICATION of EXPANDED FORMAT for AGASC1.1

- AXAF Star Catalog Needs:
  1. Provide OCC/FOT catalog for guide/aspect star selection (AGASC V1.0)
     - PCAD Control
     - Emphasizes Image Reconstruction (FOM)
     - Relative Positions Important $< 1''$
     - Absolute Positions LESS Important (Celestial Location)
  2. ASC/DS Aspect Solution 'sky model'
     - Absolute Positions IMPORTANT - for registration
     - Relative Positions to $< 0.1''$ needed if trends analysis on science targets used to calibrate ACA CTI
- AGASC V1.0 Designed For Task 1
- One catalog for tasks 1&2: less development (cost) and simplified operations (cost).
- AGASC V1.1 (and future) allows for 1&2, with expanded FITS format (new fields).
- IF New Format (additional fields), impacts OFLS/OCC development. V1.0 format viable, but increases operational complexity (FOT/SOT interactions)

What's missing from the AGASC1.0?

- Colors: Prediction of m_{ACA} from published star mags requires colors.

- Proper motion: high p.m. stars could cause problems.

- The Positions and Proper Motions (PPM) is the best complement now available.

ALL-SKY STAR CATALOGS OF POTENTIAL USE FOR AGASC

Name	Nstars	Bright Maglim?	Faint Maglim?	Colors?	P.M.?	epoch	mult?	Var?
GSC1.1	15e6	0	15	N	N	mixed	N	N
	included in AGASC1.0							
PPM	3e5	0	10	Y	Y	mixed	N	N
	added in AGASC1.1							
HIC	1e5	0	7-9	Y	Y	mixed	Y	Y
	52000 'bright' stars from SIMBAD etc.							
TIC	3e6		12	Y	flags	mixed	flags	flags
	included in GSC1.1							
TICR	1e6		12	Y	flags	1990	flags	flags
	subsample of stars likely to be in TOC, released Spring 1996							
TOC	1e6		12	Y	N	1990	flags	flags
	expected 31 March 1997, with GSC1.1 ID numbers							
GSC1.2	4e6	0	12	N	Y	mixed	N	N
	Puts GSC1.1 into Astrographic Catalog + PPM ref. frame, expected late 1997							
GSC2	1e9?	9	18	Y	Y	1990	N	N
	expected >1998							

Matching the PPM to the AGASC1.0: POSITIONS

- First determined the optimal positional matching radius. We include p.m. information, and all morphological classes. We find an optimal positional matching tolerance of $\Delta <= 10''$. To that separation, 295871 stars (99.74%) are matched.

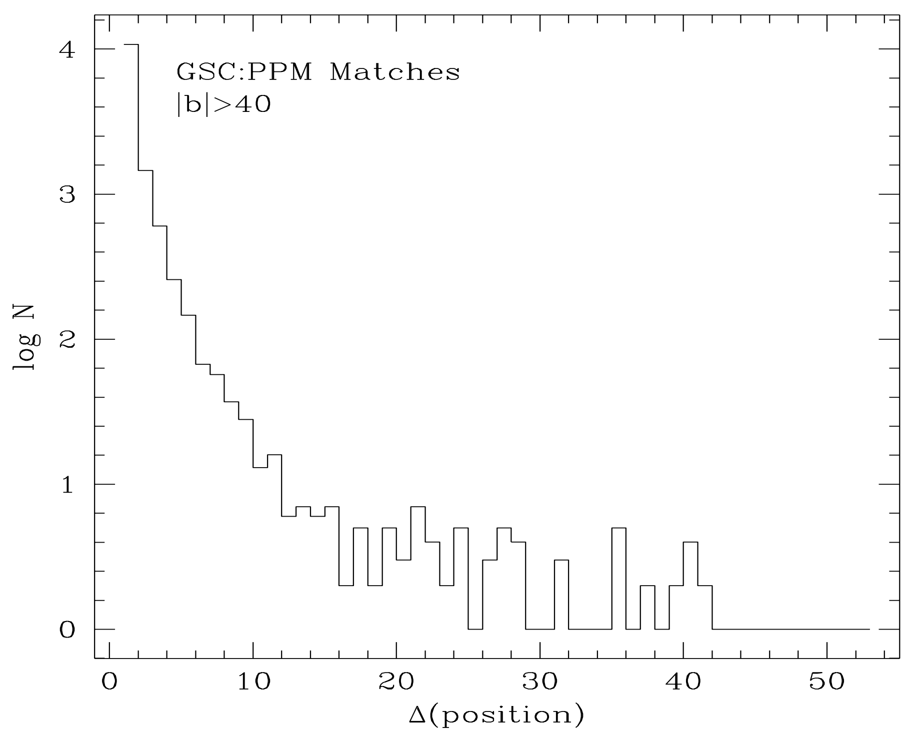

Fig. 1: Histogram of the number of stars matched between the GSC1.1 and PPM catalogs, as a function of separation. Only stars with Galactic latitude $|b| > 40°$ are included. Proper motion is accounted for. Random matches begin to predominate past $\Delta = 10''$.

Matching the PPM to the AGASC1.0: MAGNITUDES

- To verify positionally matched stars, especially in more crowded regions, we compare magnitudes between the GSC1.1 and PPM. For simplicity, and compatibility with future merged catalogs, we convert each of many AGASC1.0 magbands to a V or B band mag for comparison.

- We convert PPM spectral types to (B-V) colors by interpolation using the table of B-V for each spectral type (Allen, Astrophysical Quantites p206). We obtain or derive a dozen bandpass conversion factors α, where $V = m_{GSC} - \alpha(B-V)$.

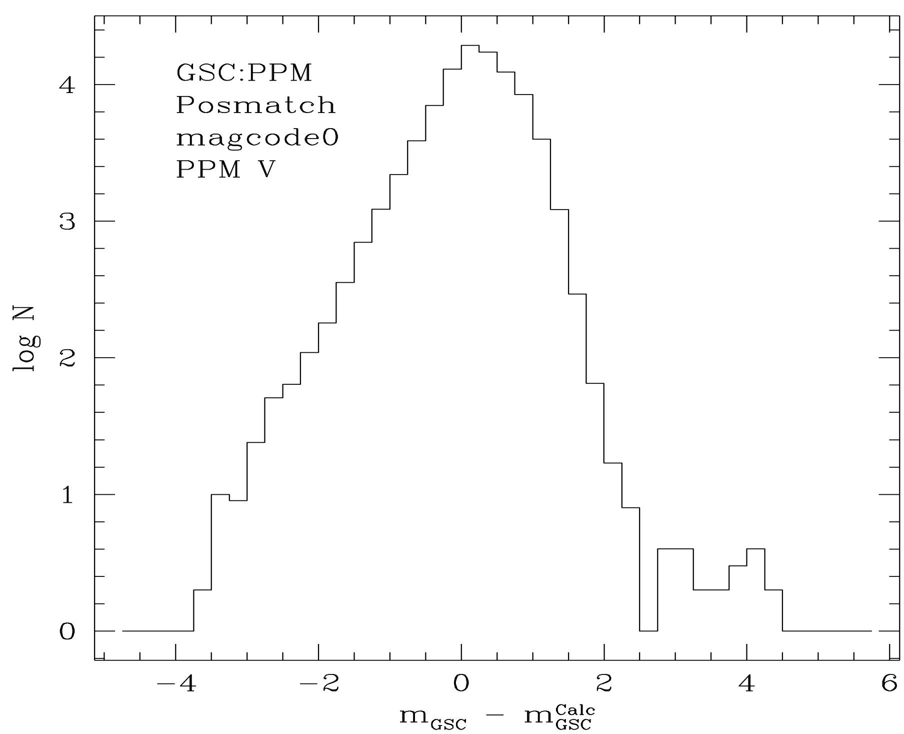

Fig. 2: Histogram of the number of stars matched in position only between the GSC1.1 and PPM catalogs, in 0.25 mag bins of $m_{GSC} - m_{GSC}^{Calc}$. Only stars with GSC1.1 magcode 0 and PPM V (not pg) mags are included. A magmatch tolerance of 2mag was adopted.

Matching the PPM to the AGASC1.0: AGASC1.1 RESULTS

The total number of PPM stars with some SpType designation retained throughout our matching process is summarized in the table below.

sample	selection	N_{stars}	% of PPM
PPM stars	none	296637	100
GSC1.1:PPM	$\Delta < 10''$	295871	99.74
GSC1.1:PPM	$\delta m < 2$mag	295274	99.54

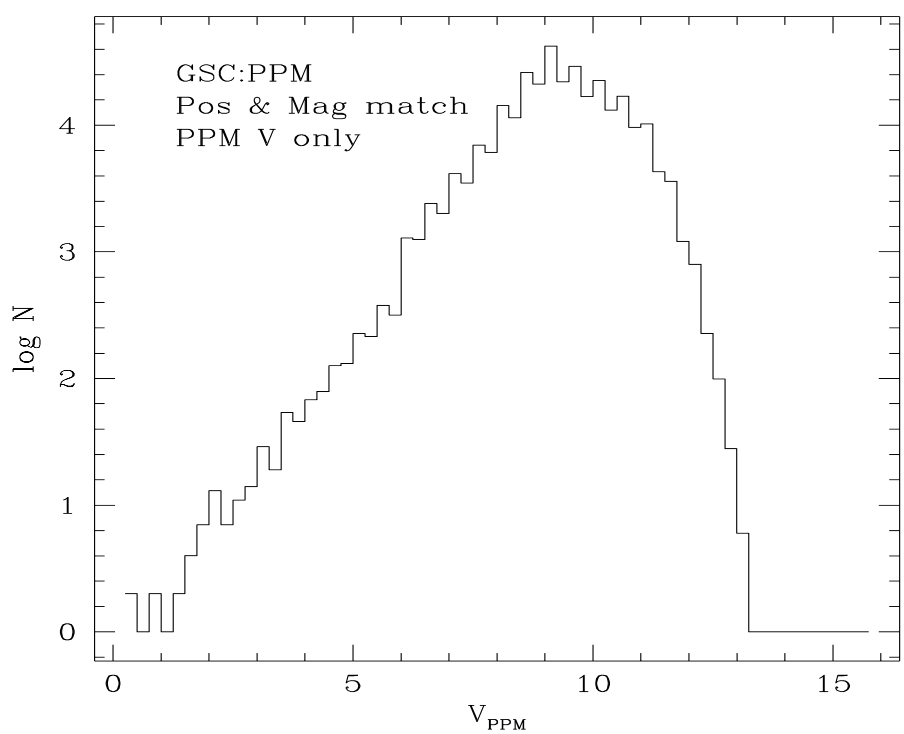

Fig. 3: Histogram of the number of stars matched in both position and magnitude between the GSC1.1 and PPM catalogs, in 0.25 mag bins of 0.25 V. Only stars with PPM V (not pg) mags are included.

AGASC1.1: INSTRUMENTAL MAGNITUDES

- We're interested in the stellar surface density to a given instrumental magnitude m_{ACA}. Conversion from V to m_{ACA} we derive by convolving the ACA bandpass with the Bruzual-Persson-Gunn-Stryker stellar spectrophotometric atlas.

- The relation goes severely non-linear redder than $(B-V)=1.4$. For the range $-0.2<(B-V)<1.3$, a good fit is $m_{ACA}=V-0.577\pm0.003(B-V)$, with rms=0.026. A decent fit for the entire color range as follows;

$$m_{ACA}=V-0.58(B-V)+0.23(B-V)^2-0.21(B-V)^4$$

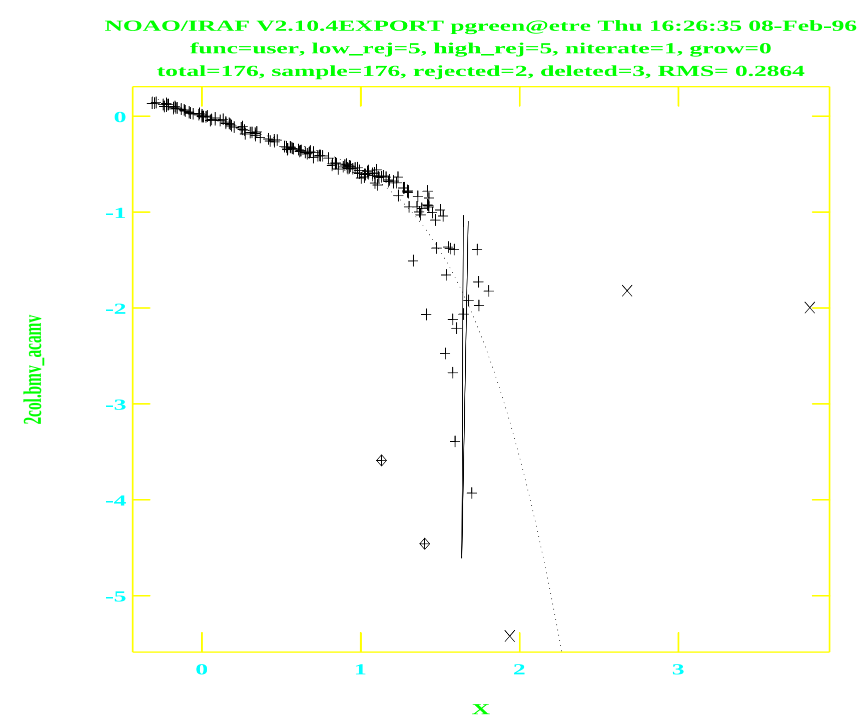

Fig. 4: Conversion from V to m_{ACA} determined by convolving the ACA bandpass with the Bruzual-Persson-Gunn-Stryker stellar spectrophotometric atlas. A 4th order polynomial fit is shown.

AGASC1.1: SURFACE DENSITY

- Having estimated m_{ACA} for each star, we can then derive surface densities at the least-populated celestial regions, primarily the Galactic plane and Galactic pole regions.

- The surface density of stars brighter than $m_{ACA} = 10.2$ (after both positional and mag matching) between the GSC1.1 and PPM catalogs is $10.1\mathrm{deg}^{-2}$ for $|b| < 10°$, and $4.7\mathrm{deg}^{-2}$ at $|b| > 80°$.

- Thus, simply matching the PPM and GSC1.1 *does not* achieve the required FOM surface density of $5.11\mathrm{deg}^{-2}$ everywhere on the sky for $m_{ACA} < 10.2$, if colors are required for every star. Inclusion of PPM stars without SpType information boosts the surface density to approximately the FOM, but without color information.

- Bahcall & Soneira (1984, ApJS, 55, 67) Galactic models suggest a total surface density of 7.6 stars deg^{-2} to $V = 10.5$, even at the NGP. Our failure to reach these densities with only the PPM is mostly due to its rather severe incompleteness for $V > 10$. The required FOM may be reached if other catalogs can be included.

AGASC1.1: NEW DATA

- As a result of merging of the GSC1.1 with the PPM, and for expected merges with other catalogs in the future, we have extended the AGASC format to include new information and references.

- New published data include proper motion, epoch, variability flag, and source catalog IDs. Cross-references are now included separately for 1) position 2) mag 3) color and 4) proper motion (p.m.). New derived data include m_{ACA}, a high p.m. flag, and spoiler star codes, which relieve the SSA of such computations.

- Four previously included items have been deleted as unecessary or redundant (PLATE_ID, POS_FLAG, SPEC_TYPE, and SP_ID).

- For a given measurement and star, the datum we include will be from the catalog which quotes the lowest errors for that measurement, or which is conatins a measurement closest to that desired (e.g., recent epoch for positions, or V bandpass for mags).

AGASC1.1: REVISED FORMAT

- The AGASC stars are grouped with regions tables, as in the original HST GSC. The AGASC consists of about 10,000 regions tables containing about 2,000 objects each. These will remain in FITS BINTABLE format, with the directory structure in FITS TABLE format.

- Stars from other catalogs that were not matched to the original GSC1.1 will be included within the appropriate regions table. Cross-references to the original star ID numbers XREF_IDx are included from the original $x = 1 - 5$ catalogs we may eventually match.

- Flags (e.g., high p.m., multiplicity, or variability are stored as numbers for future flexibility. CLASS (1I) has been extended to store a morphological multiplicity flag, MULT (ala Tycho Input Catalog).

AGASC1.1: DESCRIPTION of NEW or REVISED DATA

POSITIONS & EPOCHS: Equinox is always J2000. Proper motions are used to update positions to epoch J2000 whenever possible. The listed EPOCH is thus listed as 2000.0 for stars with p.m., and otherwise is the EPOCH of the RA and DEC measurement used.

PROPER MOTION: The p.m.s are in RA and DEC, with units milli-arcsec per year, in equinox J2000.

MAGNITUDES & COLORS: MAG and COLOR1 are the magnitude and color used to calculate MAG_ACA. If no color data are available, we assume $(B-V) = 0.7$, which is close to the data and model mean values for $V < 13$ in a variety of Galactic directions (Bahcall & Soneira 1984).

AGASC1.1: ERROR CALCULATIONS

COLOR ERRORS: For PPM stars conversion of (HD) spectral type to $(B-V)$ without reddening information yields typical color error of $\sigma_{(B-V)} \sim 0.2$mag if $(B-V) \leq 1.3$, and ~ 1.2mag if $(B-V) > 1.3$. Without a spectral subtype, we simply assume ± 1.5mag color error. This assumption is conservative for the $\geq 90\%$ of stars with $V < 19$ have $(B-V) < 1.3$.

ACA MAG ERRORS: Propagation of errors, using published mag error (σ_m), color errors $\sigma_{(B-V)}$, and formulas for bandpass conversion to V mag (via α), and from V to m_{ACA} (via polynomial coefficients C1 - C4) yields

$$\sigma^2_{ACA} = \sigma^2_m + \sigma^2_{(B-V)}[\alpha^2 + C_1 + 2C_2(B-V) + 3C_3(B-V)^2 + 4C_4(B-V)^3]^2$$

Given typical 1σ mag errors in the GSC of ~ 0.3mag, we derive errors for m_{ACA} of ± 0.4 mag for $(B-V) \leq 1.3$, and ± 1.3mag if $(B-V) > 1.3$. All these errors reflect that no reddening is yet included when converting from spectral type to color.

AGASC1.1: NOTES on CODES & FLAGS

CLASS: (classification codes; first 5 from GSC1.1)

```
0 - star
1 - galaxy
2 - blend or member of incorrectly resolved blend.
3 - non-star
5 - potential artifact
6 - Known multiple system (ala Hipparcos)
```

(1 is rare, and hand-entered; galaxies successfully processed by the software have a classification of 3. Code 4 is unused.)

VAR: (variability codes; following Hipparcos)

```
(blank): the star is not a known or suspected variable
1: suspected variable, with a suspected variation <2 mag
2: suspected variable, with a suspected variation >2 mag
3: known variable, with an  variation >0.2 mag
4: known variable, with large amplitude (> 2 mag),
     for which an ephemeris was necessary
5: known variable, with a variation <0.2 mag
```

CATIDs:

```
0: No associated catalog
1: GSC1.1
2: PPM
3: Tycho Output Catalog
4: undetermined catalog
5: undetermined catalog
```

AGASC1.1: SPOILER CODES for ASPECT STARS

ASPQ1: (Spoiler Quality code 1 for Aspect Stars)

0: No neighbors within $\leq 20''$

1: Spoiler within $15 < \delta\theta <= 20''$ with $\delta m \geq 4$

2: Spoiler within $15 < \delta\theta <= 20''$ within $\delta m < 4$

3: Spoiler with $\delta\theta <= 5''$ with $\delta m \geq 4$

4: Spoiler within $5 < \delta\theta <= 15''$ with $\delta m \geq 4$

5: Spoiler with $\delta\theta <= 5''$ with $\delta m < 4$

6: Spoiler within $5 < \delta\theta <= 15''$ with $\delta m < 4$

7: Spoiler with $\delta\theta \leq 20''$ and with $\delta m \leq 1$, or multiple spoilers

ASPQ2:

0: Stars has no known p.m. or p.m.$< 0.5''$/year

1: Stars with p.m.$\geq 0.5''$/year

AGASC1.1: SPOILER CODES for ACQUISITION STARS

- The region of interest around an acquisition star is of variable size, because the mis-point error depends on the length of the slew. For aspect stars the region of interest is of fixed size.

ACQQx: We assign six quality codes for each of 6 slew ranges, of size 30deg, from 0 to 180deg. For each ACQQx, we catalog the magnitude difference of the brightest star in a circle that is $2 \times \sqrt{(2)} \times (x/6) \times 133''$ in radius around the AGASC star. The first circle is therefore $62''$ in radius. The magnitude difference is defined as $(m_{\mathrm{spoofer}} - m_{\mathrm{AGASC}})$ in the ACA bandpass.

- The mag limit for acquisition stars is different, because we need only be sure that the potential spoofer is below the lower level discriminator (LLD) of the ACA search.

The response/calibration of the ACA may vary with time, so $(m_{\mathrm{spoofer}} - m_{\mathrm{AGASC}})$ may need to be a variable parameter. We have conducted tests using an allowable mag difference of 1.62, and find sufficient numbers of acquistion stars even for 180° slews. The nominal value of this parameter is still under investigation, but must allow for at least 1) the errors in cataloged magnitudes m_{ACA} in the AGASC, and 2) ACA Errors, e.g., the variation in the responsivity over the FOV. 3% is listed in SE32.

WHAT'S MISSING from the AGASC?

- Better positions needed, since pos. errors drive CTI on-orbit calibrations

- Colors for more stars needed to achieve FOM at high Galactic latitude.

- Incomplete for red stars. Goal of $V = 14$ is set by dimmest $m_{ACA} = 10$, where the reddest (few %) stars have $m_{ACA} - V \approx 4$.

- More accurate mags/colors for better estimates of m_{ACA}, and better estimates of aspect reconstruction quality.

AGASC1.2: Merging with the Tycho Output Catalog

- Most of the remaining deficits in the AGASC can be remedied by inclusion of the Tycho Output Catalog. Tycho was an instrument aboard Hipparcos sattelite.

- TOC will have about million stars. Completeness still unspecified, but close to 100% to $V = 10.5$ in most regions. To that magnitude, the TOC boasts
  — magnitude precision of 0.05mag for a non-variable star.
  — color precision better than 0.06mag in $(B - V)$.
  — position errors typically less than 0.01 arcsecond.

- Public release expected around 4/97. A listing of the stars likely to be included is already available. The final TOC format will be available this summer.

- Incorporation into the AGASC1.2 should be simple: TOC stars will already have GSC ID numbers, obviating positional matching and mag matching. Spoiler codes will still need to be derived.

OPTIMIZING the AGASC: The GSC2.0

- A European team is currently improving GSC1.1 astrometry using the Astrographic Catalog. Expected release in late 1997 as GSC1.2. Includes ~ 4 million stars $V < 12$.

- The second HST Guide Star Catalog, GSC2.0 will be constructed from digitized plates of the second Palomar sky survey (POSS-II) and a southern survey conducted at the AAO.
  — Reliable mags and $(B - R)$ colors will be available for $^{12<R<}_{\sim 18}$
  — Position errors will be reduced from $\sim 0.4''$ to $\sim 0.15''$.
  — Mag errors similarly reduced
  — Proper motions will be available via comparison to GSC1
  — Would provide the only available color info at the faint, red end of the AGASC.

- A complete GSC2.0 is not expected until > 1999. Some cooperative arrangement might drive cataloging if mission timeline gives sufficient warning ($^{>}_{\sim 1 mo}$).

- GSC2.0 stars applicable to AXAF represent only 5 to 10% of the total number of stars in the GSC2 to $V = 18$

OPTIMIZING the AGASC: Including Onboard Data

- RECALIBRATION of DERIVED ACA MAGS:

1) Current intrumental mag predicted based on stellar spectral libraries and crude lab ACA bandpass. Actual ACA mags for stars of a wide range of spectral types will be accumulated during the first few months of the mission, and it may prove important to generate more accurate mags for the catalog from the V, B-V data. (Alternately, new transformations could be incorporated into SSA).

2) Further recalibration may prove necessary on a longer timescale, if the Trends Analysis processing detects a significant change in the ACA color response.

- MEASURED ACA MAGS:

1) Actual ACA mags for individual stars are optimal, and should be included in the catalog immediately for targets that are REVISITED within 1 year.

2) For single-visit fields, mag info should go into yearly update of AGASC.

3) Create and continue to update an 'AXAF Optical Sky Survey (AOSS):

— incorporate of uncatalogued stars

— spoiled or spoiler stars

— useable ACQ/ASPECT stars

SUMMARY

- The PPM catalog has been merged with the AGASC1.0 to add color and p.m. information.

- The resulting AGASC1.1 nearly meets the FOM of 5.1 stars/deg^2, but not quite.

- New data, both derived and published, along with a new format that should be used in all future versions, allow for simple effective use of the AGASC by the SSA.

- FITS version of AGASC1.1 will be delivered by 9/96 to MSFC, per contract.

- The inclusion of the Tycho Output Catalog in 1997 should push the AGASC1.2 past all requirements.

- Inclusion of stellar data acquired post launch will further optimize the catalog.

Action Items From 9th MPWG Meeting

I. SI Activitiy Descriptions – Command Level

A. HRC

- Mike Juda will summarize primary observation-related items

  → identification of additional activities and command-level breakdown work in progress

B. ACIS

- Jonathon Woo will summarize primary observation-related items

  → identification of additional activities and command-level breakdown work in progress

C. ACA

- Science-driven calibration activities being developed

Action Items From 9th MPWG Meeting - Cont.

II. HRMA Preheating Prior to Eclipse

Issue: Prior to eclipse, it may be advantageous to preheat telescope in order to facilitate faster post-eclipse recovery time. This practice may depend upon the duration of the eclipse which would then necessitate decision-making by the OFLS based upon eclipse duration.

Status: Until thermal studies and post-eclipse power-up scenarios are complete, it is not clear whether this practice will be implemented. Further, it is not yet known how this will depend upon eclipse duration.

Recommendations:

1. Assume this activity will be implemented and make necessary changes to OFLS needed to accommodate this. If changes are not minor, revisit this issue.

Or

2. Accept such activities as done by hand by FOT. Eclipses are somewhat rare, so this would be plausible.

Updates to ACIS Observing Contraints

Issue: SIM thermal design is being reinvestigated in the context of new ACIS thermal information.

→ Possibility of additional cooling through Y-side of SIM.

→ This will introduce new pointing constraints.

Status: SIM Delta-CDA is still ~ 7 weeks away. Currently, it appears that holes in Y-side of SIM will not be necessary.
Recommendations: Proceed with currently known constraints, but anticipate modification from SIM Delta-CDA.
Note: In order to keep focal plane temperature below max. allowable (50C), no more than 30 minutes direct exposure of radiators to sun. Following any direct exposure, minimum of 3 hours cooldown required before next exposure.

→ This shouldn't be a problem during routine operations since the ACIS radiator should never be illuminated by sun. If this should occur, however, (e.g. during a maneuver) then the cooldown will need to be planned.

AXAF OFLS

Miscellaneous Questions

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May 29, 1996

Guide Star Selection Questions

FID Light Column Spoilers:

- Do they affect star acquisition only?
- Or, must they be taken into account along with dither during star tracking?

Near Neighbor and Column Spoilers:

- Do they affect star acquisition across quadrant boundaries?
- Do they affect star tracking across quadrant boundaries (ignoring dither)?
- Is the avoidance region dependent on the dither rate?

SI to ACA Alignment Questions

OFLS AD&SC has a requirement to perform SI to ACA alignment processing

Currently the design and algorithm are TBD

What is the operational requirement for SI to ACA alignment?

- Is the SI to ACA alignment a health and safety issue?
- What is the turn-around time for SI to ACA alignment?
- What is the difference between what the ASC does with respect to SI to ACA alignment and what the OFLS would do?
- Will the ASC update the SI to ACA alignment parameters in the AXAF Characteristics?

AXAF OFLS

Large Angle Maneuver Algorithm

G. Welter

Computer Sciences Corporation

May 29, 1996

Agenda

- Maneuver Constraints
- Maneuver Validation
- Theorems for A-priori Valid Eigenvector Maneuvers
- Maneuver Segmentation

Maneuver Constraints (1 of 3)

Based on TRW (SE-11k) diagrams, the constraints can be written as:

Power	$\lvert Y \bullet S \rvert \leq L_P$	$L_P \cong \sin(10^\circ) \cong 0.174$
Illumination	$X \bullet S \leq L_L$	$L_L \cong \cos(45^\circ) \cong 0.707$
Solar array shadowing	**Covered by power constraint**	

Maneuver Constraints (2 of 3)

Maneuver Constraints (3 of 3)

Maneuver Validation (1 of 3)

Transform the sun vector and the premaneuver spacecraft x and y axes into a “prime” frame in which the x-prime axis is the maneuver eigenaxis

Define a matrix that transforms spacecraft vectors during the maneuver into the prime reference frame

Calculate the extrema of Y•S and X•S as a function of maneuver angle in the prime reference frame

If the extrema do not

- violate the defined constraints
- or the violation occurs at an angle larger than the total maneuver angle

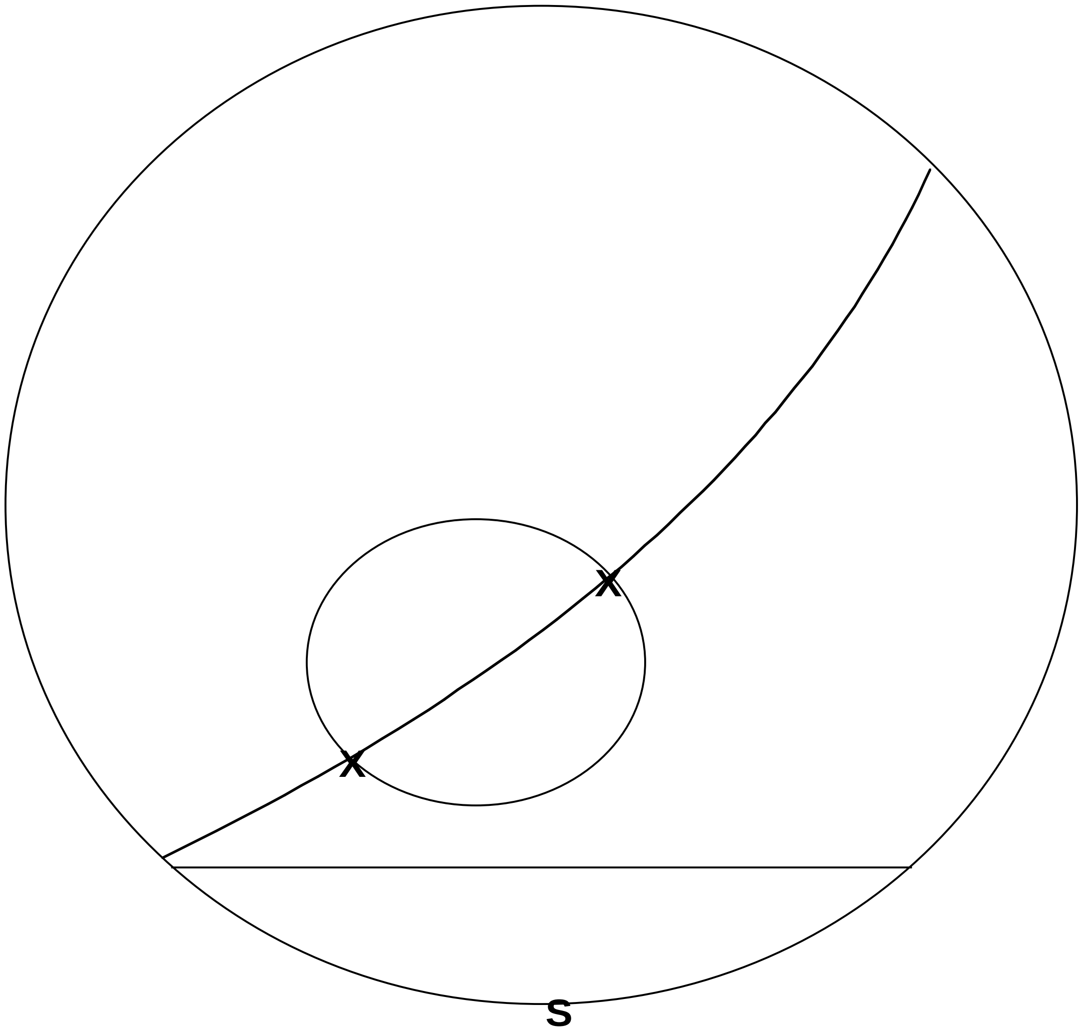
then the maneuver is valid

Maneuver Validation (2 of 3)

Certain classes of maneuvers can be eliminated a priori to expedite processing

- **no power violation if the maneuver angle $\leq$ 90 degrees and the initial and final roll angles are within ε of 0 degrees**
- **no illumination violation if the small circle through the initial and final target locations, centered at the midpoint between the targets, does not intersect the Sun avoidance constraint zone**

Maneuver Validation (3 of 3)



Theorems for A-priori Valid Eigenvector Maneuvers (1 of 4)

Theorem 1a:

Let the sun be at one of the poles of the celestial sphere surrounding the spacecraft. Take two attitudes with X-axis pointings along the same line of longitude. If the most extreme roll angle for either of the two attitudes does not exceed the smallest roll angle limit associated with any pitch angle along the maneuver, then the eigenvector maneuver connecting the two attitudes will not violate the sun roll constraint anywhere along the maneuver path.

Theorems for A-priori Valid Eigenvector Maneuvers (2 of 4)

Lemma 1a:

If the absolute value of the roll constraint angle is a nondecreasing function of spacecraft pitch angle throughout the pitch range sampled by an eigenvector maneuver that begins and ends on the same line of longitude, and if the maximum magnitude of the initial and final roll deviations is less than the minimum magnitude of roll constraint for spacecraft pitch at either the initial or final attitude, then the roll (i.e., power) constraint will not be violated during the course of the maneuver.

Theorems for A-priori Valid Eigenvector Maneuvers (3 of 4)

Theorem 2:

Given two attitudes on the same latitude line and with the same sun role angle, the eigenvector maneuver that connects them will be such that (1) the spacecraft X-axis arc for the maneuver remains on the latitude line of the attitudes, and (2) the sun roll angle remains constant throughout the maneuver.

Maneuver Segmentation (1 of 3)

Case 1: Direct maneuver

Case 2: Maneuver in 2 segments

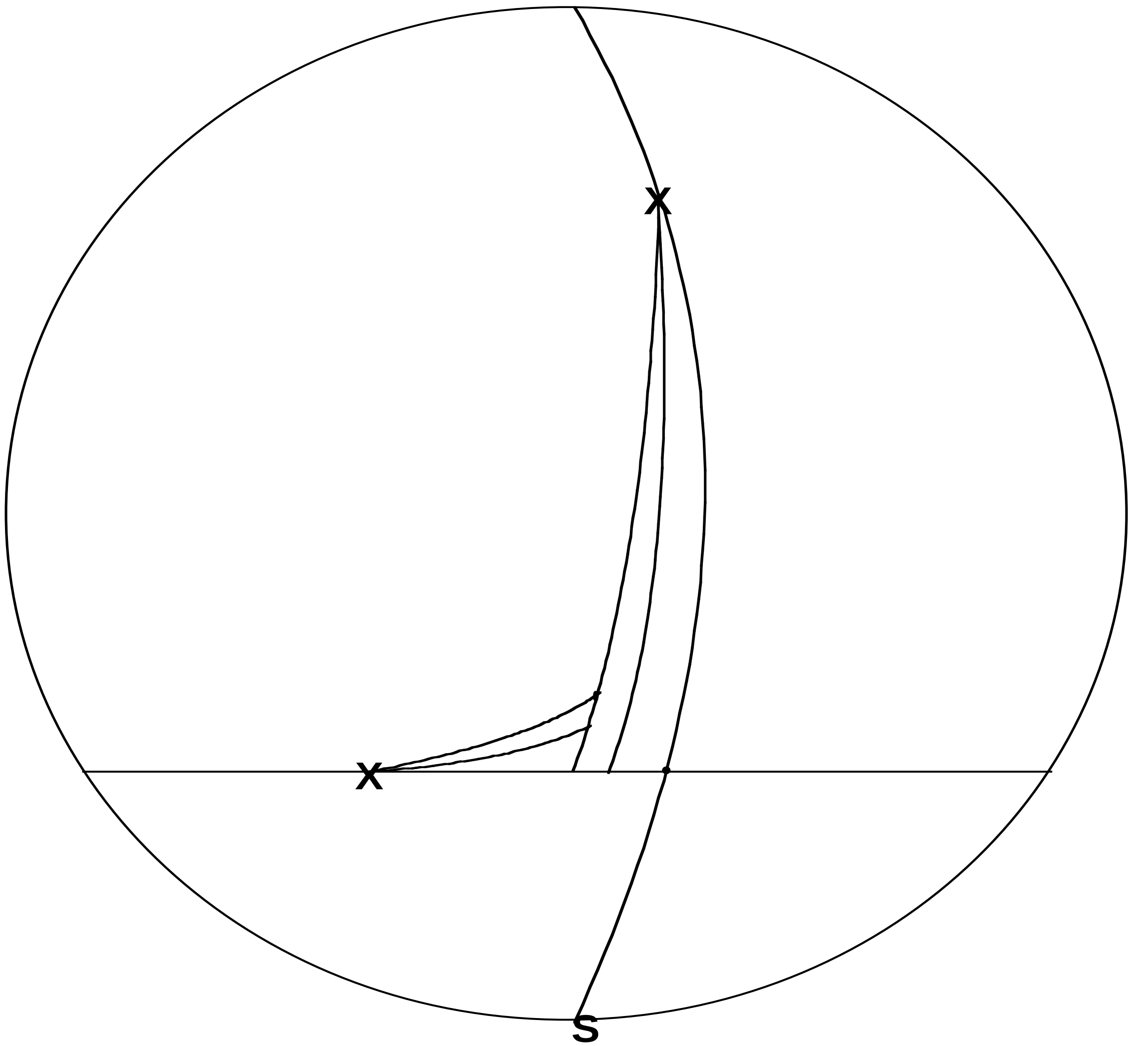
- **Initially, calculate maneuver as a pitch along longitude followed by rotation along latitude**
- **Adjust maneuver segmentation point towards direct maneuver to minimize total maneuver path over both segments**

Case 3: Maneuver in 3 segments

- **Additionally, add roll maneuver at the "pitch" segment end-point nearest the anti-Sun**

Maneuvers will be segmented only if driven by observation priority or time constraints

Maneuver Segmentation (2 of 3)



Maneuver Segmentation (3 of 3)

Question: Is the nondecreasing roll constraint angle operationally acceptable (allows use of Lemma 1a)?

Consequence: Some maneuvers for maneuver angles larger than 90 degrees that cross the 90 degree pitch line and have non-zero initial and final roll angles may require 4 maneuver segments